I. C. 7510 JUNE 1949

UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY

BUREAU OF MINES
JAMES BOYD, DIRECTOR

RECEIVED
JUN 22 1949
O. S. U. LIBRARY

INFORMATION CIRCULAR

ACCIDENT EXPERIENCE

IRON-ORE MINES, LAKE SUPERIOR DISTRICT

1940 - 47

BY

FRANK E. CASH

DEPARTMENT OF THE INTERIOR

1849 1949

A Century of Conservation

I. C. 7510,
June 1949.

INFORMATION CIRCULAR

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

ACCIDENT EXPERIENCE IRON-ORE MINES, LAKE SUPERIOR DISTRICT 1940-47[1]

By Frank E. Cash[2]

CONTENTS

	Page
Introduction	1
Acknowledgments	2
Mining methods	2
Injury experience	3
Table 1. - Injury data, annual, all mines, 1940-1947	4
Table 2. - Comparison of frequency and severity rates, iron-ore mines, 1940-1947	5
Table 3. - Injury data, by operations and methods, all mines, 1940-1947	6
Table 4. - Disabilities, 1940-1947	8
Table 5. - Injuries by years, causes, operations, and methods, 1940-1947	9
Table 6. - Severity of injuries by causes, 1944-1947	10
Summary	10
Appendix. - Calculations, 8-year trend of injuries, iron-ore mines, Lake Superior district	13

ILLUSTRATIONS

Fig.		Follows page
1.	Frequency, all mines, 1940-1947, with 8-year trend line	2
2.	Severity all mines, 1940-1947, with 8-year trend line	2

INTRODUCTION

The producing iron-ore ranges in the Lake Superior district are the Marquette and Menominee in Michigan, the Gogebic in Michigan and Wisconsin, and the Cuyuna, Mesabi, and Vermilion in Minnesota. These ranges produce about 85 percent of the iron ore mined in the United States. The accident experience in connection with this production is better than that of the regions producing the remaining 15 percent. Production and shipments vary slightly from year to year owing to stockpiling underground ore during the winter, or nonshipping, season but closely approximate each other over a period of years.

---

[1] Work on manuscript completed August 1948. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7510."

[2] Supervising engineer, Bureau of Mines, Duluth, Minn.

Original from THE OHIO STATE UNIVERSITY

This information circular supplements, combines, and continues the data contained in Information Circulars 7321[3] and 7410[4], including statistics for 1946 and 1947.

Whereas the title "Accident Experience" is used for uniformity and logical indexing throughout this report, "injury" will be used as a general term to apply to disabilities of all degrees.

During the 8-year period 1940 to 1947, inclusive, 619,054,023 long tons of iron ore was shipped from the Lake Superior district.[5] Michigan and Wisconsin shipped 117,828,939 tons, or 19.03 percent of the total, and employed approximately 9,260 men. Minnesota shipped 501,225,084 tons, or 80.97 percent of the total, and employed an approximate annual average of 12,260 men. The tons produced and shipped per man employed in Minnesota is much greater than in Michigan and Wisconsin, owing to the large open-cut production in Minnesota.

ACKNOWLEDGMENTS

This consolidated report was made possible through the cooperation of the operating companies, the Lake Superior Mines Safety Council, and the Lake Superior Iron Ore Association. To these organizations and to John H. Strome, safety director of the Inland Steel Co., who compiled the statistics in 1946 and 1947, the author expresses sincere appreciation.

MINING METHODS

In Minnesota, most of the ore is produced from open cut mines. In Michigan and Wisconsin, a large percentage of the ore is produced from underground mines. Open-cut mines are all considered as utilizing the same method; the principal difference is in the transportation of ore and waste.[6] The underground mines use three mining methods, which, in order of their relative production, are top slicing, sublevel caving, and stoping.

The average number of operating mines in the district during the 8-year period was 122, of which 72 were open-cut and 50 underground operations. During this same period, an average of 17 underground mines employed top slicing, 17 sublevel caving, and 16 stoping as their principal mining method.

During the years 1946 and 1947, a few mines have changed their method of mining from top slicing and stoping to sublevel caving. In 1947 the 50 operating underground mines were divided as follows: top slicing, 14; stoping, 16; and sublevel caving, 20.

---

[3] Cash, Frank E., and Larsen, Reuben D., Accident Experience, Iron-Ore Mines, Lake Superior District, 1940-1943: Bureau of Mines Inf. Circ. 7321, 1945, 9 pp.

[4] Cash, Frank E., Accident Experience, Iron-Ore Mines, Lake Superior District, 1940-1945: Bureau of Mines Inf. Circ. 7410, 1947, 11 pp.

[5] Tonnage figures from Lake Superior Iron Ore Association.

[6] Johnson, John A., and Cash, Frank E., Transportation of Iron Ore, Open-Cut Mines, Lake Superior District: Bureau of Mines Inf. Circ. 7458, 1948, 24 pp.

Digitized by Google Original from THE OHIO STATE UNIVERSITY

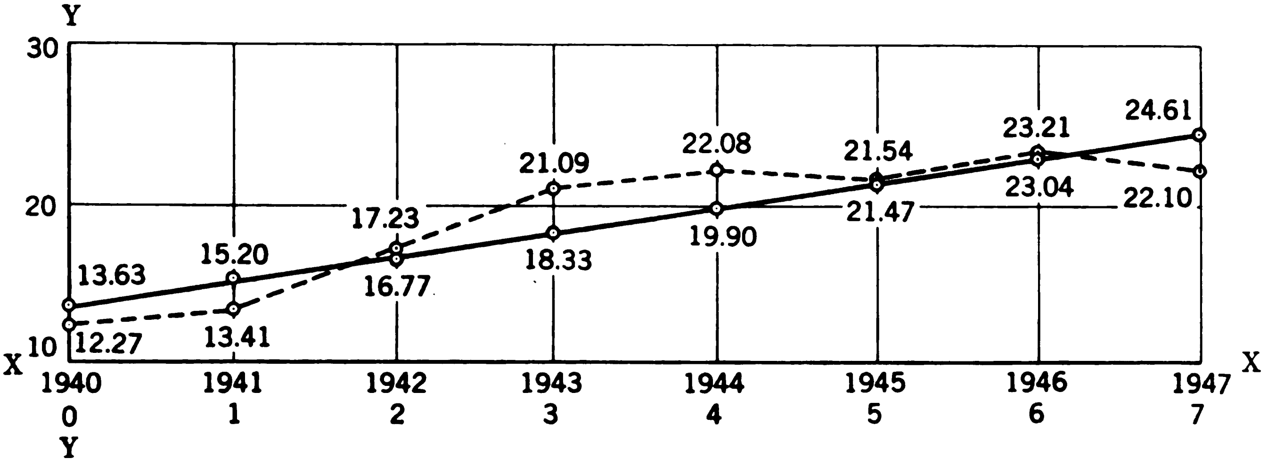

Figure 1. - Frequency rates all mines, 1940-1947, with 8-year trend line.

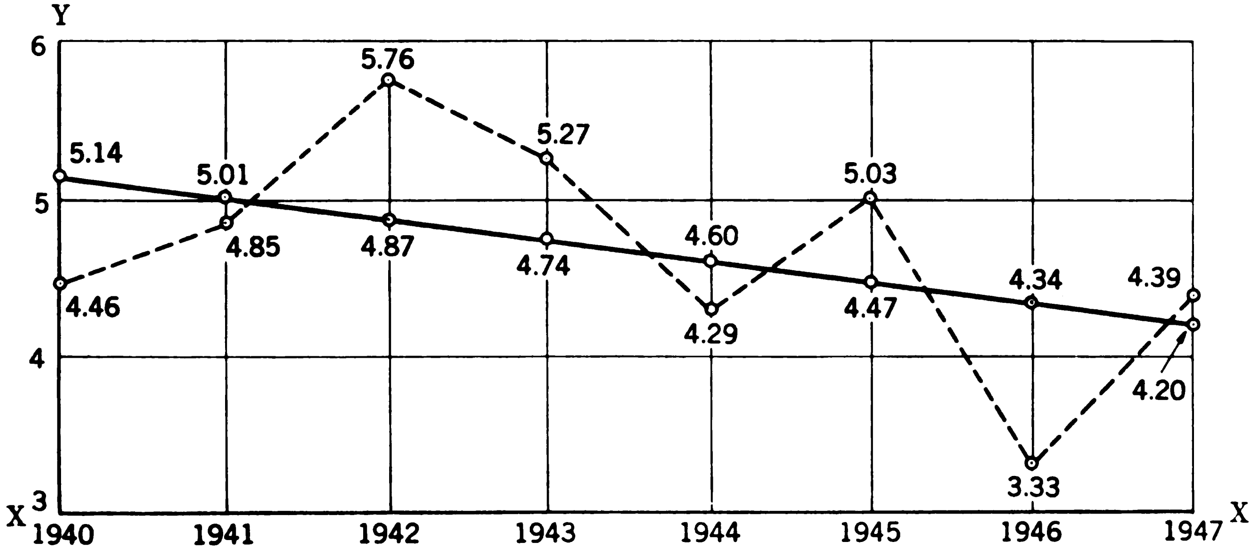

Figure 2. - Severity rates all mines, 1940-1947, with 8-year trend line.

INJURY EXPERIENCE

The injury data were taken largely from those furnished by the operating companies and were compiled and published by the Lake Superior Mines Safety Council.[7] However, they are supplemented, for the purpose of comparison, with figures published by the Bureau of Mines in reports of the National Safety Competition and Annual Surveys of Metal Mine Accidents.[8] The discussion of these data is based entirely upon observations and opinions of the author.

During the years 1940 to 1945, inclusive, increased production was absolutely necessary, irrespective of manpower, but no acute shortage existed, notwithstanding that the Armed Services took many men from the mines in the district, necessitating their replacement by men with less experience. During 1946 production dropped, but in 1947 it increased sharply. In these two years a number of men were released from the Services and re-entered the mines. This combination of circumstances had, and continues to have, a definite effect upon the number of injuries in the mines of the Lake Superior district.

Table 1 gives (by years and totals for all mines) the shipments, man-hours worked, number of injuries, and frequency and severity rates covering injuries for the 8-year period.

The frequency rate is the number of lost-time injuries per million man-hours worked, and the severity rate is the number of days lost because of injuries per thousand man-hours worked. A lost-time injury is one that caused loss of time beyond the day or shift on which the injury occurred. In calculating severity, temporary disabilities are figured as the actual calendar days lost, including holidays and Sundays, whereas fatal and permanent injuries are weighted according to the United States Bureau of Mines "Scale of Time Losses for Weighing Deaths and Permanent Injuries", adapted from the American Standards Association.

Table 1 shows that shipments increased during the first 3 years, decreased during the next 4 years, and increased materially during 1947. The man-hours worked increased during the first 4 years of the 8-year period, decreased during the next 3 years, and increased in 1947. The frequency rate increased for the first 5 years and fluctuated during the last 3 years, with a slight downward trend in 1945. The severity rate fluctuated somewhat but did not vary appreciably from the average for the period.

A clearer picture of the trend of injuries is shown by figures 1 and 2. In figure 1 the annual frequency rates are shown by a dotted line, and the frequency-rate trend, determined by the method of least squares, is shown by the heavy straight line. The trend line shows an increase from 13.63 in 1940 to 24.61 in 1947, indicating an increase of 80.6 percent in the frequency rates for the 8-year period.

---

[7] Carmichael, Percy A. (1941 and 1942 proceedings), Larsen, Reuben D. (1943 and 1944 proceedings), Mahon, Stanley A., and Borgeson, George A. (1946 proceedings), and Strome, John H. (1947 and 1948 proceedings), Lake Superior Mines Safety Council.

[8] Adams, W. W., Moyer, Forrest T., and others.

TABLE 1. - Injury data, annual, all mines, 1940-1947

Year	Gross tons shipped	Man-hours worked	Days lost account injuries	Injuries				Frequency	Severity
				Fatal	Partial permanent	Temporary	Total		
1940................	63,948,846	31,217,310	1/139,303	17	7	359	383	12.27	4.46
1941................	80,747,859	41,239,423	200,114	25	13	515	553	13.41	4.85
1942................	93,008,726	45,912,672	264,701	34	12	745	791	17.23	5.76
1943................	85,962,168	51,863,102	1/273,157	34	25	1,035	1,094	21.09	5.27
1944................	81,857,005	42,023,601	1/180,368	21	29	878	928	22.08	4.29
1945................	75,960,871	40,010,662	1/201,365	25	29	808	862	21.54	5.03
1946................	59,587,730	32,963,546	1/109,760	12	28	725	765	23.21	3.33
1947................	77,980,818	43,039,615	188,797	24	28	899	951	22.10	4.39
Total..........	619,054,023	328,269,931	1,557,565	192	171	5,964	6,327	19.27	4.74

1/ Includes one total permanent disability.

Original from THE OHIO STATE UNIVERSITY

In figure 2 the annual severity rates are shown by the dotted line, and the severity rate trend, determined by the method of least squares, is shown by the heavy straight line. The trend line shows a decrease from 5.14 in 1940 to 4.20 in 1947, indicating a decrease of 18.3 percent in the severity rates for the 8-year period.

The method of least squares is a generally accepted method of determining the constants for a trend that can be represented by a straight line. The step-by-step procedures for determining these straight-line trends are appended to this report.

The breakdown of injuries for the 8-year period was as follows: 187 fatal, 5 permanent total-disabling, 171 partial-permanent-disabling and 5,964 temporary disabling. The 6,327 fatal and nonfatal injuries resulted in 1,557,565 weighted and actual days lost time.

There was one fatal or total-permanent injury for each 3,224,240 tons shipped, one partial-permanent for each 3,620,199 tons, and one temporary disability for each 103,793 tons. For each fatal or total permanent there were 0.89 partial permanent and 31.06 temporary disabling injuries.

For purposes of comparison, table 2 lists the frequency rates for the iron-ore mines in the United States, the frequency and severity rates for the metal mines entered in the National Safety Competition, and the iron-ore mines in the Lake Superior district for the years 1940 to 1947, inclusive, in so far as they were available.

TABLE 2. - Comparison of frequency and severity rates iron ore mines, 1940-1947

	Iron-ore mines, United States	Metal-mines entered in National Safety Competition		Iron-ore mines Lake Superior district	
Year	Frequency	Frequency	Severity	Frequency	Severity
1940.....	19.63	14.47	6.09	12.27	4.46
1941.....	23.08	20.14	6.85	13.41	4.85
1942.....	24.41	20.62	5.55	17.23	5.76
1943.....	25.57	24.21	6.27	21.09	5.27
1944.....	24.78	25.42	5.70	22.08	4.29
1945.....	25.33	31.36	7.35	21.54	5.03
1946.....	27.59	41.02	9.37	23.21	3.33
1947.....	-	26.13	4.47	22.10	4.39

Table 3 gives injury data (including total and combined figures) for the 8-year period by types of operations and methods of mining.

All injuries are potentially serious, and their rate of occurrence must be decreased to imporve the over-all injury experience; however, after an injury occurs, the lost time, suffering, reduction in production, and expenses are reflected in severity rather than frequency. Therefore, severity rate is used as the basis for comparison.

TABLE 3. - Injury data, by operations and methods, all mines, 1940-1947

Operations and methods	Man-hours worked	Days lost account injuries	Injuries					
			Fatal	Partial-permanent	Temporary	Total	Frequency	Severity
General shops	27,518,461	39,703	5	11	143	159	5.78	1.44
Open cuts	125,061,563	460,356	54	66	1,347	1,467	11.73	3.68
Concentrators[1]	2,028,525	8,433	1	1	23	25	12.32	4.16
Top slicing	62,348,918	324,093	37	24	1,595	1,656	26.56	5.20
Stoping	38,254,340	228,732	30	25	833	888	23.21	5.98
Sublevel caving	73,058,124	496,248	65	44	2,023	2,132	29.18	6.79
All operations and methods	328,269,931	1,557,565	192	171	5,964	6,327	19.27	4.74

[1] 1946 and 1947 only. Previously "open cuts and concentrators."

Under the heading Operations and Methods, "General Shops" are those within a company doing general repair work for one mine or a group of mines. In most instances shops are connected with each mine, and the shop injury experience is included with that of the individual mine. "Concentrators" may beneficiate ore from one or several mines. "Open-cut", "top slicing", "stoping", and "sublevel caving" are methods used by various mines.

The most hazardous operation or method is sublevel caving, for which both frequency and severity rates are consistently high. This is due largely to the bad type of ground, which requires such a method and in which other methods could not be used. Nevertheless, the injury rates, both frequency and severity, for all operations and methods in this district, are favorable when compared with other iron ore and metal mining districts in the country.

The heading "Miscellaneous Development," used in the previous published reports, 1940 to 1945, has been discontinued, and the data have been prorated and included in the proper mining method. It was felt that shaft sinking and rock raising was as much a part of the method as was drifting and crosscutting. This change naturally makes differences under stoping, top slicing, and sublevel caving in the corresponding table of the previous published report.

In table 4 the injuries are listed for the various operations and methods with the length of disability for each type of injury.

Table 5 shows the fatal and permanent-total, permanent-partial, and temporary disabling injuries, by causes, for all mines for the 8-year period. Since publication of a similar report for 1940 to 1945, inclusive, the injuries listed as "not classified" have been reviewed, and a large number have been classified and included under specific causes. This changes a number of the cause totals in the 1940 to 1945 report but results in a more accurate detailed presentation of the injuries by causes. Examination of table 5 will reveal that of the 192 fatal and total-permanent disabilities, 82 (42 percent) were caused by falls and slides of ground and 21 (10.9 percent) were caused by haulage. Other causes, in order of their resulting fatal and total-permanent injuries were persons falling (shafts, raises, banks, etc.), 12; explosives, 10; falling material (shafts, raises, etc.), 10; loading equipment (shovels, scrapers, etc.), 8; machinery (moving), 7; railroad cars and locomotives, 7; persons falling (slipping and stumbling), 5; electricity (shocks and burns), 5; cages, skips, and buckets, 4; drilling equipment, 4; suffocation (natural gases), 3; inrushes of mud and water, 3; handling material, 2; runs of ore and rock (chutes and bins), 2; falling material (other than ground), 1; and not classified, 6. Flying objects, hand tools, and mine fires caused no fatal or total-permanent disabilities.

The 21 causes of the injuries listed in table 5 are rearranged in table 6 in order of the severity of injuries, giving the number of injuries, total days lost, and average days lost per injury for the years 1944 to 1947, inclusive. The most severe cause of injury was inrushes of mud and water, with 9 injuries, 3 of which were fatal, resulting in 2,067.4 days lost per injury. The least severe and also the least frequent cause of injury was suffocation from natural gases, resulting in one injury with 7 days lost time. The most frequent cause was handling material, with 603 injuries resulting in 24,743 lost days, or an average of 41.0 days per injury. During this period there were 3,506 injuries resulting in 680,290 days lost, an average of 194.0 days lost per injury.

TABLE 4. - Disabilities, 1940-1947

Operations and methods	Fatal[1]			Partial permanent[1]			Temporary			All injuries		
	Number injuries	Total days lost	Average days lost	Number injuries	Total days lost	Average days lost	Number injuries	Total days lost	Average days lost	Number injuries	Total days lost	Average days lost
General shops....	5	30,000	6,000.0	11	3,641	331.0	143	6,062	42.4	159	39,703	249.8
Open cuts........	54	324,000	6,000.0	66	76,553	1,159.9	1,347	59,803	44.4	1,467	460,356	313.8
Concentrators[2]..	1	6,000	6,000.0	1	1,800	1,800.0	23	633	27.5	25	8,433	337.3
Top slicing......	37	222,000	6,000.0	24	26,382	1,099.3	1,595	75,711	47.5	1,656	324,093	195.7
Stoping..........	30	180,000	6,000.0	25	18,816	752.6	833	29,916	35.9	888	228,732	257.6
Sublevel caving..	65	390,000	6,000.0	44	33,080	751.8	2,023	73,168	36.2	2,132	496,248	232.8
All operations and methods[3]..	192	1,152,000	6,000.0	171	160,272	937.3	5,964	245,293	41.1	6,327	1,557,565	246.2

[1] Weighted disabilities.

[2] 1946 and 1947 only; previously with open-cuts.

[3] Includes four permanent total disabilities.

TABLE 5. - Injuries by years, causes, operations, and methods, 1940-1947

Causes		General shops		Concentrators		Open cuts		Top slicing		Stoping		Sublevel caving		Totals		Total	Total
		1946	1947	1946	1947	1946	1947	1946	1947	1946	1947	1946	1947	1946	1947	1940-1945	1940-1947
Falls and slides of ground (ore and rock)	F	0	0	0	0	2	1	0	1	1	2	3	2	6	6	70	82
	PP	0	0	0	0	0	0	0	0	0	0	1	2	1	2	9	12
	T	0	0	0	0	4	6	31	28	17	12	63	87	115	133	919	1,167
Haulage (belt, truck and locomotive)	F	0	1	0	1	1	1	0	1	1	0	0	2	2	6	13	21
	PP	0	1	0	0	0	0	0	0	1	0	1	2	2	3	10	15
	T	0	0	0	0	32	34	12	7	7	10	22	36	73	87	394	554
Explosives	F	0	0	0	0	0	0	0	0	0	0	1	1	1	1	8	10
	PP	0	0	0	0	0	0	0	1	0	0	1	0	1	1	4	6
	T	1	0	0	0	0	2	0	0	1	0	1	1	3	3	36	42
Machinery (moving)	F	0	0	0	0	0	0	0	0	0	0	0	1	0	1	6	7
	PP	2	2	0	0	4	4	0	0	0	1	2	1	8	8	22	38
	T	3	2	1	2	12	12	5	2	4	4	10	12	35	34	171	240
Loading equipment (shovels, scrapers, etc.)	F	0	0	0	0	1	0	0	0	0	0	0	1	1	1	6	8
	PP	0	0	0	0	0	0	0	0	0	0	1	2	1	2	9	12
	T	0	1	0	0	9	4	0	2	1	5	4	17	14	29	175	218
Persons falling (shafts, raises, banks, scaffolds)	F	0	0	0	0	0	0	0	0	0	2	1	0	1	2	9	12
	PP	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1
	T	0	4	2	2	9	5	10	5	10	0	8	22	39	38	180	257
Railroad cars and locomotives	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7
	PP	0	0	0	0	0	1	0	0	0	0	0	0	0	1	6	7
	T	0	0	0	1	0	7	0	0	0	0	0	1	0	9	33	42
Persons falling (slipping and stumbling)	F	0	0	0	0	1	0	0	0	0	0	0	0	1	0	4	5
	PP	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	2
	T	0	1	1	2	11	21	13	1	14	17	21	27	60	69	391	520
Falling material (shafts, raises, etc.)	F	0	0	0	0	0	0	0	1	0	0	0	2	0	3	7	10
	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
	T	0	0	0	0	2	1	10	1	5	8	15	22	32	32	205	269
Electricity (shocks and burns)	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5
	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	T	1	0	0	0	0	0	1	0	1	1	2	0	5	1	19	25
Suffocation (natural gases)	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T	0	0	0	0	0	0	0	0	0	1	0	0	0	1	19	20
Cages, skips, and buckets	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
	T	0	0	0	0	0	0	0	0	0	0	0	1	0	1	35	36
Handling material	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
	PP	1	0	0	0	2	2	1	0	1	0	1	2	6	4	8	18
	T	6	7	4	6	34	28	41	35	17	18	51	68	153	162	657	972
Runs of ore and rock (chutes and bins)	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T	0	0	0	0	0	1	1	6	0	17	0	23	1	47	40	88
Falling material (other than ground)	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
	T	0	4	0	0	1	22	12	0	1	7	6	28	20	61	177	258
Drilling equipment	F	0	0	0	0	0	2	0	0	0	0	0	0	0	2	2	4
	PP	0	0	0	0	0	2	0	0	0	0	0	2	0	4	11	15
	T	0	0	1	0	12	13	1	0	11	5	7	23	32	41	116	189
Flying objects	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PP	0	0	0	1	0	1	0	0	1	0	0	1	1	3	17	21
	T	0	1	0	0	5	9	9	3	9	10	18	23	41	46	164	251
Hand tools	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PP	0	0	0	0	3	0	0	0	1	0	1	0	5	0	4	9
	T	2	3	1	0	16	7	10	5	11	4	21	34	61	53	173	287
Mine fires	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T	0	0	0	0	0	1	0	0	3	0	1	0	4	1	7	12
Inrushes, mud and water	F	0	0	0	0	0	0	0	0	0	0	0	2	0	2	1	3
	PP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	T	0	0	0	0	0	0	0	0	0	0	0	1	0	1	7	8
Not classified	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
	PP	1	0	0	0	0	0	0	0	0	0	0	0	1	0	4	5
	T	1	0	0	0	15	7	10	8	5	7	6	28	37	50	422	509
Totals	F	0	1	0	1	5	4	0	3	2	4	5	11	12	24	156	192
	PP	4	3	0	1	9	10	1	1	5	1	9	12	28	28	115	171
	T	14	23	10	13	162	180	166	103	117	126	256	454	725	899	4,340	5,964
Grand Total		18	27	10	15	176	194	167	107	124	131	270	477	765	951	4,611	6,327

F - Fatal. PP - Partial permanent. T - Temporary disability.

TABLE 6. - Severity of injuries, by causes, 1944-1947

Causes	Number of injuries	Days lost	Average days lost
Inrushes, mud and water....................	9	18,607	2,067.4
Explosives.................................	20	28,377	1,418.9
Railroad cars and locomotives..............	22	16,768	762.2
Electricity (shocks and burns).............	11	6,174	561.3
Falls and slides of ground (ore and rock)..	504	228,920	454.2
Cages, skips, and buckets..................	18	7,967	442.6
Persons falling (shafts, raises, banks, scaffolds, etc.).........................	150	49,392	329.3
Haulage (conveyor, truck, locomotive, etc.)	319	95,132	298.2
Machinery (moving).........................	135	38,037	281.8
Falling material (shafts, raises, etc.)....	183	44,275	241.9
Loading equipment (shovels, scrapers, etc.)	101	24,180	239.4
Drilling equipment.........................	152	26,694	175.6
Flying objects.............................	139	16,116	115.9
Persons falling (slipping and stumbling)...	212	12,495	58.9
Not classified.............................	552	28,908	52.4
Falling material (other than ground).......	120	5,529	46.1
Handling material..........................	603	24,743	41.0
Hand tools.................................	188	6,448	34.3
Runs of ore and rock (chutes and bins).....	62	1,482	23.9
Mine fires.................................	5	39	7.8
Suffocation (natural gases)................	1	7	7.0
All causes.................................	3,506	680,290	194.0

SUMMARY

An average of 122 mines are operated by 26 companies in the Lake Superior district, which annually produces 85 percent of the iron ore mined in the United States. Individual open-cut mines produce and ship 15,000 to 15,000,000 tons annually, and the underground mines from 40,000 to 1,000,000 tons a year. Virtually all of the underground and some of the open-cut ore is shipped as mined, but in recent years more and more of the open-cut ore is beneficiated in local concentrating plants before shipment.

During the 8-year period of 1940 to 1947, inclusive, more than 619 million tons of ore was shipped and 328 million man-hours worked in all operations. The injuries in the district are relatively fewer and less severe than in other metal-mining districts. However the frequency rate has shown an upward trend, increasing from 12.27 in 1940 to 22.10 in 1947, with a weighted average of 19.27 for the 8-year period. The severity rate increased from 1940 to 1945, but decreased in 1946 and 1947, giving an over-all downward trend for the 8-year perio

General shops worked a total of 27-1/2 million man-hours with 159 injuries, distributed as follows: 5 fatal, 11 partial-permanent, and 143 temporary disabilities. These injuries caused 39,703 days lost time.

Concentrators and open-cut mines were combined from 1940 to 1945, but with more concentrating plants and a variance in rates between them and open-cut mines, the two were carried separately in 1946 and 1947. During the 2-year period, concentrators, with 2 million man-hours worked, had 25 injuries, distributed as follows: 1 fatal, 1 partial-permanent, and 23 temporary disabilities. These injuries resulted in 8,433 lost days.

Open-cuts represented 125 million man-hours of work with 1,467 injuries, distributed as follows: 54 fatal, 66 partial-permanent, and 1,347 temporary disabilities. These injuries resulted in 460,356 lost days.

Top slicing, with over 62-1/4 million man-hours worked, had charged against it a total of 1,656 injuries, distributed as follows: 37 fatal, 24 partial-permanent, and 1,595 temporary disabilities. These injuries caused 324,093 days lost time.

Stoping, with a working time over the 8-year period of 38-1/4 million man-hours, was charged with 888 injuries, distributed as follows: 30 fatal, 25 partial-permanent, and 833 temporary disabilities. These injuries have resulted in 223,736 days lost.

Sublevel caving with a working time of 73 million man-hours had 2,132 injuries charged against it distributed, as follows: 65 fatal, 44 partial-permanent, and 2,023 temporary disabilities. The days lost in this method of mining have been 496,248.

Most of the mines are highly mechanized and during the 8-year period produced large tonnages of iron ore and maintained old equipment in relatively good repair with a minimum of replacement parts or new equipment when such was difficult to obtain.

Electric cap lamps are furnished and used in all underground mines. Employees wear hard hats, safety-toe shoes, and safety goggles for certain classes of work in and around the mines.

With the exception of a few small producers, the companies maintain safety departments with safety supervisors, engineers, and inspectors. The Lake Superior Mines Safety Council serves as a clearing house for various safety-operating problems and has proved its value by reducing accidents and injuries of the several companies that comprise the organization.

All of the companies operating underground mines maintain mine-rescue equipment and personnel trained in its use. Some of the companies maintain central mine rescue stations serving two or more mines relatively close together, and others maintain a separate station at each mine regardless of the proximity of the mines to each other.

Prior to 1940, most of the companies encouraged and sponsored first-aid training for their employees, and several had 100-percent employee first-aid training. Since 1940 there has been very little of such training, and the small amount has been largely confined to supervisors.

Most companies have some form of printed or mimeographed operating and safety rules for the guidance of employees and supervisors. Various types of regular safety meetings are held by most of the companies; some include all employees, others include employee safety committees and supervisors, and some are attended by supervisors only.

At most open-cut mines the employees are required to wear protective shoes or boots in summer, but in extremely cold weather they are permitted to discontinue using them. Protective hats are worn in all underground and some open-cut mines.

A number of companies provide goggles, and some issue them with corrective lenses. A few companies require their use throughout the shift for all employees. Many companies make it optional with the individual workmen to wear them where and when necessary or leave it to the supervisory force to require their use for selected types of work.

In underground mines virtually all haulage is with electric trolley locomotives. The exceptions are at least two mines that use conveyors for main haulage, and several mines use chute-to-drift flight conveyors.9/ Haulage in open-cut mines is by electric, Diesel-electric, and steam locomotives, trucks, and conveyors.

About half of the underground mines maintain stench-warning systems for warning underground employees in case an emergency necessitates quick removal of the men.10/

Blast-hole drilling in open-cut mines is done largely by electrically-operated well- or wagon-type drills, with a few gasoline or electrically operated auger-type drills for horizontal holes in soft material. In underground mines, pneumatic percussion-type drills are in general use, with a few rotary auger-type drills for soft material. Electrically driven rotary core drills are used in one mine where the ore is very hard and in several mines for drilling deep holes.11/ Virtually all drilling is done wet.

The blasting in open-cut mines is done with dynamite or "Nitramon" detonated with cap and fuse, electric blasting cap, or detonating fuse. Dynamite detonated with fuse and cap, generally is used in underground blasting. In extremely wet places, heavy blasting, shafts, and long raises, electric delay detonators are used. Where electric blasting is used, the circuits are safely

---

9/ Johnson, John A., and Cash, Frank E., Transportation of Iron Ore, Underground Mines, Lake Superior District: Bureau of Mines Inf. Circ. 7419, 1947, 22 pp.

10/ Cash, F. E., and Johnson, Ernest W., Stench-Warming Tests, Lake Superior District Mines: Bureau of Mines Report of Investigations 3850, 1947, 23 pp.

11/ Johnson, Ernest W., and Cash, F. E., Diamond Drilling of Blast Holes Lake Superior District Iron-Ore Mines: Bureau of Mines Inf. Circ. 7317, 1945, 11 pp.

guarded by a series of blasting switches.[12] The magazines for the storage of explosives usually are well-constructed, safely located, and properly ventilated.[13]

Most of the underground mines have two or more openings to the surface and are ventilated mechanically. A few mines have excellent ventilation systems, with provisions for heating the air in cold weather. Some mines were developed years ago with little thought to long life, depth, and adequate ventilation.

Periodic dust surveys are made in most mines and concentrating plants, and remedial procedures are instigated promptly if dust counts exceed an established maximum limit.

The surface plants, old and new, are well-arranged and properly maintained. Most of the newer plant structures are of modern design and constructed with a tendency to house virtually all necessary surface units in one building. The new change houses are spacious, air-conditioned, provided with sanitary bathing and toilet facilities, and have separate rooms for street and mine clothes.[14]

In general, a determined effort is made by mining companies and their employees in the Lake Superior district to reduce the occurrence of injuries in mining iron ore. Although favorable when compared with other metal-mining districts, the trend of the frequency of injuries is increasing, which, unless reversed, eventually may result in an increase in the trend of the severity rate. This can and should be accomplished and an improvement in injury experience realized through closer coordination of efforts by management and employees.

APPENDIX

Calculations, 8-year Trend of Injuries Iron-ore Mines, Lake Superior District

Although the determination of trend lines calculated by the method of least squares is an accepted, simple algebraic method, it requires several steps.

The several steps in the determination of the frequency and severity trend lines, as developed in College Algebra by Hart, chapter XXV, "Method of Least Squares and Related Topics", are given in this appendix. This procedure refers to figures 1 and 2 and table 1 of this report.

---

[12] Petersen, Max S., and Cash, F. E., Electric Blasting Switches, Underground Mines, Lake Superior District: Bureau of Mines Inf. Circ. 7372, 1946, 11 pp.

[13] Cash, Frank E., Storage of Explosives in Underground Mines of the Lake Superior District: Bureau of Mines Inf. Circ. 7343, 1946, 9 pp.

[14] Cash, Frank E., and Stott, Roy G., Change Houses in the Lake Superior District. Bureau of Mines Inf. Circ. 7489, 1948.

Frequency, 1940-1947 (from figure 1)

When-

$$\begin{array}{ll}
X = 0; & Y = 12.27 \\
X = 1; & Y = 13.41 \\
X = 2; & Y = 17.23 \\
X = 3; & Y = 21.09 \\
X = 4; & Y = 22.08 \\
X = 5; & Y = 21.54 \\
X = 6; & Y = 23.21 \\
X = 7; & Y = 22.10
\end{array}$$

Using the straight-line equation $Y = ax + b$ and substituting the above values for X and Y, values are obtained for the eight points.

$$\begin{array}{rcl}
Y & = & ax + b \\
12.27 & = & 0 + b \\
13.41 & = & 1a + b \\
17.23 & = & 2a + b \\
21.09 & = & 3a + b \\
22.08 & = & 4a + b \\
21.54 & = & 5a + b \\
23.21 & = & 6a + b \\
22.10 & = & 7a + b \\
\hline
152.93 & = & 28a + 8b
\end{array} \quad \text{Summation equation (1)}$$

Using equation $\sum(xy) = a\sum(x^2) + b\sum(x)$

$$\begin{array}{lrcl}
\text{When-} & xy & = & ax^2 + bx \\
X = 0; & 0 & = & 0 + 0 \\
X = 1; & 13.41 & = & 1a + 1b \\
X = 2; & 34.46 & = & 4a + 2b \\
X = 3; & 63.27 & = & 9a + 3b \\
X = 4; & 88.32 & = & 16a + 4b \\
X = 5; & 107.70 & = & 25a + 5b \\
X = 6; & 139.26 & = & 36a + 6b \\
X = 7; & 154.70 & = & 49a + 7b \\
\hline
 & 601.12 & = & 140a + 28b
\end{array} \quad \text{Summation equation (2)}$$

Solving equations (1) and (2) for a and b.

$$\begin{array}{lrcll}
(2) & 140a + 28b & = & 601.12 & \\
(1) & 98a + 28b & = & 535.26 & (\text{by } 3.5) \\
\hline
 & 42a & = & 65.86 & \\
 & a & = & 1.568 & \\
(1) & 140a + 40b & = & 764.65 & (\text{by } 5.0) \\
(2) & 140a + 28b & = & 601.12 & \\
\hline
 & 12b & = & 163.53 & \\
 & b & = & 13.628 &
\end{array}$$

Substituting values for a and b in the straight-line equation $Y = ax + b$.

When-	$Y = ax + b$
$X = 0;$	$Y = 0 + 13.63 = 13.63$
$X = 1;$	$Y = (1.568)1 + 13.63 = 15.20$
$X = 2;$	$Y = (1.568)2 + 13.63 = 16.77$
$X = 3;$	$Y = (1.568)3 + 13.63 = 18.33$
$X = 4;$	$Y = (1.568)4 + 13.63 = 19.90$
$X = 5;$	$Y = (1.568)5 + 13.63 = 21.47$
$X = 6;$	$Y = (1.568)6 + 13.63 = 23.04$
$X = 7;$	$Y = (1.568)7 + 13.63 = 24.61$

As this is a straight-line equation, it is only necessary to substitute, except for checking, the first and last or any two points.

X = 0; 1940 =	13.63
X = 7; 1947 =	24.61
Difference +	10.98

10.98 ÷ 13.63 = 80.6% increase in frequency.

Severity, 1940-1947 (from fig. 2)

When-	
$X = 0;$	$Y = 4.46$
$X = 1;$	$Y = 4.85$
$X = 2;$	$Y = 5.76$
$X = 3;$	$Y = 5.27$
$X = 4;$	$Y = 4.29$
$X = 5;$	$Y = 5.03$
$X = 6;$	$Y = 3.33$
$X = 7;$	$Y = 4.39$

Using the straight-line equation $Y = ax + b$ and substituting the above values for x and y, values are obtained for the eight points.

$$
\begin{array}{l}
\underline{Y = ax + b} \\
4.46 = 0 + b \\
4.85 = 1a + b \\
5.76 = 2a + b \\
5.27 = 3a + b \\
4.29 = 4a + b \\
5.03 = 5a + b \\
3.33 = 6a + b \\
\underline{4.39 = 7a + b} \\
37.38 = 28a + 8b \quad \text{Summation equation (3)}
\end{array}
$$

Using equation $\sum(xy) = a\sum(x^2) + b\sum(x)$

When	xy	=	ax^2	+	bx	
X = 0;	0	=	0	+	0	
X = 1;	4.85	=	1a	+	1b	
X = 2;	11.52	=	4a	+	2b	
X = 3;	15.81	=	9a	+	3b	
X = 4;	17.16	=	16a	+	4b	
X = 5;	25.15	=	25a	+	5b	
X = 6;	19.98	=	36a	+	6b	
X = 7;	30.73	=	49a	+	7b	
	125.20	=	140a	+	28b	Summation equation (4)

Solving equations (3) and (4) for a and b.

$$
\begin{array}{lrcrcll}
(4) & 140a & + & 28b & = & 125.20 & \\
(3) & 98a & + & 28b & = & 130.83 & \text{(by 3.5)} \\
\hline
 & 42a & & & = & 5.63 & \\
 & a & & & = & 0.134 & \\
(3) & 140a & + & 40b & = & 186.90 & \text{(by 5.0)} \\
(4) & 140a & + & 28b & = & 125.20 & \\
\hline
 & & & 12b & = & 61.70 & \\
 & & & b & = & 5.142 &
\end{array}
$$

Substituting values for a and b in the straight line equation $Y = ax + b$:

When						
X = 0;	Y =	0	+	5.14	=	5.14
X = 1;	Y =	(-0.134)1	+	5.14	=	5.01
X = 2;	Y =	(-0.134)2	+	5.14	=	4.87
X = 3;	Y =	(-0.134)3	+	5.14	=	4.74
X = 4;	Y =	(-0.134)4	+	5.14	=	4.60
X = 5;	Y =	(-0.134)5	+	5.14	=	4.47
X = 6;	Y =	(-0.134)6	+	5.14	=	4.34
X = 7;	Y =	(-0.134)7	+	5.14	=	4.20

As it is a straight-line equation, it is only necessary to substitute, except for checking, the first and last points, or any two points.

X = 0;	1940 =	5.14
X = 7;	1947 =	4.20
Difference		-0.94

0.94 ÷ 5.14 = 18.3% reduction in severity.